(51) International Patent Classification 5 : **G21B 1/00**	**A1**	(11) International Publication Number: **WO 92/02020**
		(43) International Publication Date: 6 February 1992 (06.02.92)

(21) International Application Number: PCT/US90/06419

(22) International Filing Date: 5 November 1990 (05.11.90)

(30) Priority data:
PCT/US90/4122   20 July 1990 (20.07.90)   WO
*(34) Countries for which the regional
or international application
was filed:*   US et al.

(60) Parent Applications or Grants
(63) Related by Continuation
US   344,679 (CIP)
Filed on   28 April 1989 (28.04.89)
US   555,517 (CIP)
Filed on   20 July 1990 (20.07.90)

(71) Applicant *(for all designated States except US)*: UNIVERSI-TY OF HAWAII [US/US]; Research Corporation of the University of Hawaii , 2540 Maile Way, Honolulu, HI 96822 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : LIEBERT, Bruce, E. [US/US]; 2216 Mohala Way, Honolulu, HI 96822 (US). LIAW, Bor, Yann [US/US]; 512 Iolani Avenue, No. 302, Honolulu, HI 96813 (US).

(74) Agent: HSIA, Martin, E.; Cades Schutte Fleming & Wright, P.O. Box 939, Honolulu, HI 96808 (US).

(81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CM (OAPI patent), DE, DE (European patent), DK, DK (European patent), ES, ES (European patent), FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), GR (European patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL, NL (European patent), NO, RO, SD, SE, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US.

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: ELECTROCHEMICALLY ASSISTED EXCESS HEAT PRODUCTION

BEST AVAILABLE COPY
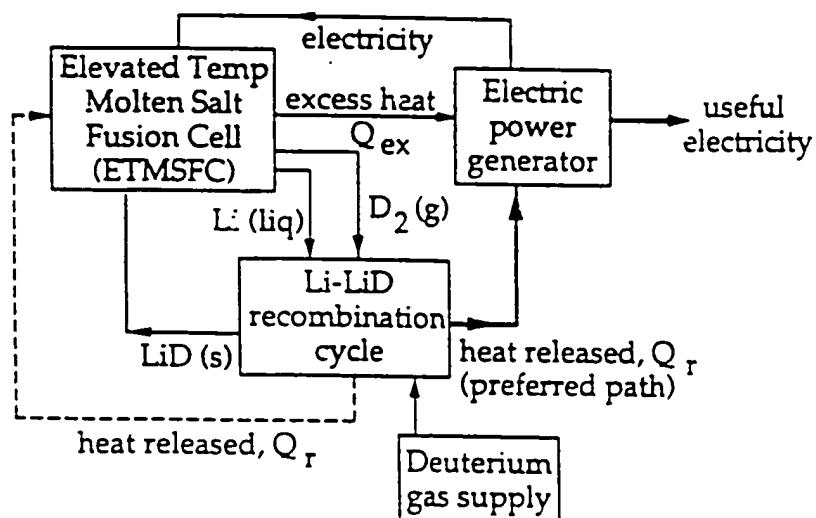
(57) Abstract

Electrochemically assisted nuclear reaction that produces excess heat at elevated temperatures by immersing a metal in an electrolyte solution comprising a molten salt containing an alkali deuteride and applying a potential and current to the electrolyte and the metal to enhance diffusion of deuterium into the metal. A recycling system utilizing metals that do not form compounds with lithium and also have very limited solubilities for lithium will increase the usefulness of the invention by recombining lith-

1   DESCRIPTION
           Electrochemically Assisted Excess Heat Production
Technical Field

           This invention relates to electrochemically-assisted
5   excess heat production. Recent reports of excess heat
     production in electrochemically-assisted metal-deuterium
     systems have been attributed to fusion.

           Nuclear fusion occurs when two nuclei of a light element
     combine in order to form a single nucleus of a heavier
10   element. Nuclear fusion is the process that causes the sun
     to shine and a hydrogen bomb to explode. The simplest
     fusion reactions between two deuterium atoms are to form (i)
     a helium-3 nucleus and a neutron or (ii) a tritium nucleus
     and a proton. The nucleus of a hydrogen atom consists only
15   of a single positively charged particle, the proton. A
     hydrogen atom's nucleus may also contain a single neutron
     and a single proton to form the hydrogen isotope deuterium.
     A hydrogen atom containing two neutrons and one proton is
     the hydrogen isotope tritium.
20   The energy in a helium nucleus is less than the energy
     in two deuterium nuclei, so that if two deuterium nuclei
     fuse to form a helium nucleus, the excess energy is
     released; this is the source of energy for a deuterium
     fusion reaction. However, because deuterium nuclei are
25   positively charged, they repel each other. Accordingly, in
     order to induce fusion, this repulsion must be overcome.
Background Art

           Scientists have sought a method for inducing controlled
     fusion reactions for decades. At this time, at least four
30   major methods have been proposed and are being studied. The
     first method, magnetic confinement, requires the creation of
     high temperature plasmas in a confined electromagnetic field
     in order to overcome the electrostatic repulsion between
     deuterium nuclei to cause them to fuse. The second method,
35   inertial confinement, attempts to overcome the electrostatic
     repulsion between deuterium nuclei by simultaneously
     compressing a deuterium cluster from all directions with
     powerful laser beams. The third method, muon-assisted

1   fusion, involves the use of muon particles to assist
     deuterium fusion. Magnetic confinement and inertial
     confinement fusions require very high energies or extremely
     expensive equipment.

5   However, the fourth method, electrochemically-assisted
     "cold fusion", appears to require only readily available
     materials and relatively inexpensive equipment.
     Electrochemically-assisted "cold fusion" has been attributed
     to deuterium-deuterium or deuterium-hydrogen fusion within a
10   metal's crystal lattice.

          In this application, the term "metal" shall be deemed to
     mean and include metals and alloys that absorb hydrogen and
     its isotopes. A deuteride is a compound with deuterium and
     a tritide is a compound with tritium. The term "elevated
15   temperatures" shall mean above ambient temperatures, say 20
     degrees Celsius.

          Metals usually form crystal lattices in which the nuclei
     of the metals are packed closely together. The crystal
     lattice of a metal also can have two or more phases,
20   depending on such factors as temperature, pressure and
     impurities. Hydrogen, including its heavy isotopes
     deuterium and tritium, can diffuse into the interstices of
     the crystal lattice. Further, if a suitable potential is
     applied to the crystal lattice, the diffusion of deuterium
25   can be enhanced so that extremely high effective pressures
     or activities of deuterium can be obtained in the crystal
     lattice. The relationship between the applied voltage and
     the effective pressure or activity of the deuterium within
     the crystal lattice can be calculated using the Nernst
30   equation. If the effective pressure or activity of the
     deuterium is sufficiently great, the deuterium nuclei may
     undergo fusion or some other nuclear process and produce
     excess heat.

          Pons and Fleischmann claim to have achieved
35   electrochemical-fusion by immersing a palladium electrode in
     heavy water with a supporting electrolyte, lithium
     deuteroxide (LiOD), and then using electrolysis to
     dissociate the heavy water. See "Electrochemically Induced

1   Nuclear Fusion of Deuterium," J. Electroanal. Chem.. 261
     (1989) 301-308, and more recently, in the same journal 287
     (1990) 293-348. However, the Pons and Fleischmann method of
     electrochemical fusion has several disadvantages.

5   First, Pons and Fleischmann employed an aqueous
     solution, which limits the usefulness of their invention to
     a temperature range below the boiling point of water
     (approximately 100 degrees Celsius at 1 atmosphere
     pressure). This low-temperature operation leads to low

10   efficiency in commercial applications.
         Second, the Pons and Fleischmann invention requires the
     use of expensive materials such as Pd and its alloys because
     the aqueous solution will result in an oxide film on almost
     all other host metals. This oxide film will normally impede

15   diffusion of the deuterium into the metal. Accordingly, the
     host metal must be a noble metal that will not form
     diffusion-impeding oxide films in the presence of water or
     oxygen.
         Third, Pons and Fleischmann used a negative Pd electrode

20   which will cause positive deuterium ions and positive alkali
     ions to migrate to the negative Pd electrode to form alloys
     with Pd and impede diffusion of the deuterium into the
     metal.
         Fourth, the Pons and Fleischmann invention dissociates

25   its solvent, heavy water, and therefore requires substantial
     amounts of solvent in order to function, unless recombined.
         Fifth, the Pons and Fleischmann invention creates
     substantial amounts of deuterium and oxygen gas, thereby
     creating a danger of a chemical explosion.

30   Sixth, the Pons and Fleischmann invention might not work
     efficiently with metals including palladium. At the
     temperatures employed by Pons and Fleischmann, palladium has
     two single crystalline phases. However, at elevated
     temperatures, Pd as well as many other metals have only one

35   crystalline phase. Each crystalline phase has a different
     packing density and atomic arrangement and it is therefore
     unlikely that fusion or other possible nuclear processes
     will take place under the same conditions for the differe--

1 crystalline phases. Thus, having multiple crystalline
phases might reduce the efficiency of any nuclear reaction
that was induced.

Attempts to achieve electrochemical fusion, as claimed
5 by Pons and Fleischmann, have reportedly been unable to
detect fusion by-products consistently. The present
inventors are unable to determine whether their invention
employs fusion or some other reaction or principle.
Accordingly, the present inventors describe their invention
10 only as relating to a "nuclear process"; the determination
of the theory of the reaction taking place is left to
others.

It is therefore an object of this invention to provide
an electrochemical method of inducing a nuclear reaction at
15 a temperature that will be commercially useful for power
generation.

It is a further object of this invention to provide such
a method that will avoid the formation of diffusion-impeding
oxide films on the host metal.
20 It is a further object of this invention to provide such
a method that will enable operation at a temperature
sufficiently high that the host metal is in a single phase.

It is a still further object of this invention to
provide such a method that will use negatively charged
25 deuterium ions.

It is a still further object of this invention to
provide such a method that will not dissociate the solvent
of the electrolyte.

It is a still further object of this invention to
30 provide such a method that will employ inexpensive
materials.

It is a still further object of this invention to
provide such a method that will not generate oxygen so that
the risk of a chemical explosion may be avoided.
35 It is a still further object of this invention to
provide a recycling system for deuterium and lithium.

Disclosure of Invention

These and other objects are achieved by dissolving a

1   hydrogen isotope-containing component capable of providing a
    source of a hydrogen isotope (preferably an alkali
    deuteride) into a substantially non-aqueous molten salt to
    form an electrolytic solution, immersing a metal into the
5   electrolytic solution and then applying a sufficiently high
    electrical potential and current density to the metal and
    the electrolytic solution to dissociate the alkali deuteride
    and to force sufficient amounts of deuterium into the metal
    at sufficient pressures to increase the activity of the
10 deuterium and to initiate the nuclear reaction.
        Using a liquid salt avoids oxidation of the host metal
    because of the lack of oxygen and also provides an extremely
    reducing environment that eliminates any oxides that may
    form on the metal's surface. Use of a liquid salt also
15 permits a wide range of working temperatures, depending on
    the particular salt selected. For example, a salt could be
    selected that was solid at room temperature, but would melt
    at operating temperatures.
        The avoidance and elimination of oxidation allows the
20 use of many different metals because no oxide film will
    impede diffusion of the deuterium into the metal. Thus,
    less expensive metals can be used. The lack of oxygen also
    avoids the possibility of a chemical explosion from
    accumulated oxygen with hydrogen and its isotopes.
25   The ability to use a higher temperature allows the
    generation of heat at commercially valuable temperatures and
    also enhances deuterium diffusion into the metal. It also
    allows operation at a temperature in which the host metal is
    in a single phase.
30   Because the source for deuterium is the alkali deuteride
    dissolved in the liquid salt, the salt can be selected so
    that dissociation of the alkali deuteride will not
    dissociate the salt. Further, the dissociation potential
    the alkali deuteride (preferably lithium deuteride) is
35 lower than the dissociation potential of heavy water.
    Therefore, the power required for the electrolysis is
    reduced substantially.
    Brief Description of the Drawings

6

1   Figure 1 is a schematic view of an apparatus according
to this invention.
        Figure 2 is a cross sectional view of the apparatus in
Figure 1 through the line 2-2.
5   Figure 3 is a schematic view of an improved mass and
energy flow arrangement according to this invention
incorporating a lithium deuteride recycling system.
        Figure 4 is a schematic diagram of the lithium deuteride
recycling system incorporated into the electrolysis cell.
10   Best Mode for Carrying Out the Invention
        Referring to Figure 1, a crucible 10 (preferably
aluminum) is filled with a eutectic lithium chloride-
potassium chloride (LiCl-KCl) salt and heated above 350
degrees Celsius (and preferably between 370 and 400 degree
15   Celsius) in an inert gas environment (preferably argon or
helium) at atmospheric pressure or greater to form a molten
salt solution. Alternatively, the salt could be heated in
an evacuated environment or in a deuterium environment.
Sufficient alkali deuteride (preferably lithium deuteride
20   (LiD)) is then dissolved into the molten salt to form a
saturated electrolytic solution 12. However, the solution
is not required to be saturated and is expected to be
unsaturated under operating conditions. A positive
electrode 14 made of a transition metal, preferably
25   palladium, which has been thermally annealed (preferably
torched and remelted), is immersed in the electrolytic
solution 12, as is a negative electrode 16, preferably made
of aluminum. At the preferred temperature, the palladium
positive electrode 14 will be in a single phase during
30   reaction.
        A constant current density (preferably 200 milliamps/cm^2
or higher) is passed at a sufficiently high rate between the
electrodes 14 and 16 to dissociate the lithium deuteride and
to increase the activity of the deuterium in the positive
35   electrode 14 so that a nuclear reaction takes place.
Experimental results indicate that reaction takes place at
1.8 volts or higher. The experiments have been reproduced,
but not consistently. The preferred salt for the practice

1   of this invention is a lithium chloride-potassium chloride
     eutectic molten salt, the preferred electrolyte is lithium
     deuteride and the preferred host metal is palladium, as
     indicated above. However, other salts and other alkali
5   deuterides may be employed in the practice of this
     invention, as may other metals. For example, the molten
     salt could be an organometallic salt, an alkali halide, or
     an alkali hydroxide, and their mixtures. The alkali
     deuteride could be lithium deuteride, sodium deuteride or
10   potassium deuteride. Alternatively, alkaline earth metal
     (Group IIA) deuterides (such as magnesium deuteride, calcium
     deuteride, or strontium deuteride) or Group IIIA metal
     deuterides (such as aluminum deuteride) could be employed.
     The metal also could be a transition metal, such as
15   titanium, palladium, vanadium, tantalum, niobium, zirconium,
     hafnium, nickel, iron, or cobalt, and their alloys, and
     intermetallics based on the lanthanum and actinium series.
          Many of the advantages of using a molten salt solution
     in forcing hydrogen into a metal lattice are described and
20   discussed in the article entitled "Controlled Electrolyte
     Environments and Their Use For Studying and Modifying
     Materials Properties: Potentials for Employment in Practical
     Devices," Solid State Ionics 28-30 (1988) 1078-1083.

                         RECYCLING SYSTEM
25   A problem that arises with use of the cell structure
     depicted in Fig. 1 is that deuterium gas evolved from the
     palladium anode escapes. Further, lithium is depleted from
     the system and combines with the aluminum cathode to form
     Li_xAl_y (nominally "LiAl"), which is a by-product of no
30   further use in this application. These reactions make the
     system discontinuous because it runs down relatively
     quickly; it is anticipated that the system would run down in
     a matter of hours or days instead of months or years. This
     also results in a low efficiency in the use of LiD
35   electrolyte and adds to the cost of the system.
     Accordingly, it would be desirable to provide some type of
     recycling system for the deuterium gas and lithium.
          Figure 3 shows a schematic mass and energy flow

8

1   for a lithium and deuterium recycling system. This
    recycling is preferably achieved by using tungsten,
    molybdenum, nickel or iron for the cathode, preferably
    molybdenum. These metals do not form compounds with lithium
5   and also have very limited solubilities for lithium, so that
    the lithium will plate on the surface. As indicated above,
    the excess heat from the fusion cell is used to generate
    useful electricity. Some of this electricity is used by the
    cell for electrolysis of the lithium deuteride solution.
10 Unused deuterium gas evolves from the palladium electrode
    and, because the cell's temperature is higher than the
    melting point of lithium, liquid lithium plates on the
    cathode. The deuterium gas and liquid lithium are
    recombined to form lithium deuteride. This recombination
15 should release additional heat due to the negative enthalpy
    of formation and could be used for additional power
    generation. The lithium deuteride then is recycled through
    the fusion cell.

         A separate deuterium gas supply is preferred in order to
20 insure proper formation of lithium deuteride because
    deuterium will be consumed in the reaction creating excess
    heat.

         Figure 4 shows a cell similar to the cell shown in
    Figure 1, with a lithium and deuterium recycling system. As
25 is the case in Figure 1, a crucible 20 (preferably of the
    same material as the cathode, namely molybdenum) is filled
    with a lithium chloride-potassium chloride (LiCl-KCl)
    eutectic salt and initially heated by a heating element 24
    above 350 degrees Celsius (and preferably between 370 and
30 400 degrees Celsius) in an inert gas environment (preferably
    argon or helium) at atmospheric pressure or greater to form
    a molten salt solution. A similar system using pure
    deuterium gas or an evacuated environment can also be
    employed. Sufficient lithium deuteride (LiD) is dissolved
35 into the molten salt to form a saturated electrolytic
    solution 22. A positive electrode 26 preferably made of
    torched and annealed palladium, but having a significant
    horizontal extent is immersed in the electrolytic ...

1   22. A negative electrode 30, comprising a metallic sponge
    (to present a large reaction surface) made of a metal that
    does not form alloys with lithium and has little lithium
    solubility, such as tungsten, molybdenum, nickel or iron
5   (and preferably molybdenum) is also immersed in the
    electrolytic solution but spaced apart from and above the
    positive electrode. The negative electrode 30 is
    approximately horizontally coextensive with the interior of
    the crucible 20. The positive electrode 26 should be
10 electrically isolated from the rest of the cell.

        In operation, excess deuterium D_2 that does not react
    with the positive electrode 26 bubbles upwards into the
    negative electrode 30. Simultaneously, lithium Li that has
    been dissociated from the lithium deuteride plates onto the
15 negative electrode 30 and is held in its absorbent
    structure. The electrochemically-generated deuterium D_2 gas
    that is not incorporated into the host lattice then reacts
    with the lithium Li to form lithium deuteride LiD, which
    redissolves into the electrolytic solution 22. Preferably,
20 a source of additional deuterium S is provided below the
    negative electrode 30 to react with the lithium Li in the
    negative electrode 30. Any lithium Li that does not react
    with deuterium D_2 gas in the negative electrode 30 will
    float to the surface as a liquid because the electrolytic
25 solution 22 is heated above lithium's melting point. Excess
    deuterium or deuterium from the source S then can react with
    the lithium Li floating on the surface of the electrolytic
    solution 22.

        It is anticipated that this recycling system would
30 increase the lifetime of a system by at least one, and
    perhaps more, orders of magnitude.

                        TORCHED PALLADIUM
        It is preferable that the palladium used in the cell be
    torched palladium which has a very porous structure. It
35 appears to be much more effective than other forms of
    palladium. Any other means to prepare such a porous
    structure may be obvious in this application and may be
    usable as well.

1 Industrial Applicability

The apparatus and process of this invention have a wide
range of applications. In the utility industry, these
applications include electric power generation, dwelling
5 heating, and self-sustaining power generation for remote
areas. In the manufacturing and processing industries, the
applications could include chemical production and materials
production. In transportation, the applications could
include vehicles, such as cars, trains, buses, trucks,
10 ships, and aircraft. Other applications are limited only by
the imagination.

It will be apparent to those skilled in the art that
many modifications may be made without departing from the
scope and spirit of this invention. The term "transition
15 metals" shall include transition metals and their alloys and
also shall include elements in the lanthanum and actinium
series and intermetallics based thereon. The term "molten
salt" shall mean and include mixtures of salts. The
invention has been described only with respect to single
20 preferred embodiment and no limitation is to be implied or
inferred except as may be set forth in the appended claims.

1   CLAIMS

     What is claimed is:

     1.   A process for inducing nuclear reactions at temperatures
     above ambient temperature, comprising:

5   applying an electrical potential and current density to
     an electrolytic solution having a hydrogen isotope-
     containing component capable of providing a source of a
     hydrogen isotope and a metal, by applying an electrical
     potential and current density to said metal and solution to

10   diffuse the hydrogen isotope into the metal to initiate the
     nuclear reaction; and

          enhancing the rate of diffusion and activity of said
     hydrogen isotope by minimizing oxide formation on the metal.

     2.   A process for effecting enhanced diffusion and

15   dissolution of deuterium into a metal using
     electrochemically assisted means, comprising:

          dissolving an alkali deuteride into a substantially non-
     aqueous molten salt to form an electrolytic solution;

          immersing a metal in said electrolytic solution; and

20   applying a sufficiently high electrical potential and
     current density to said metal and said electrolytic solution
     to enhance the diffusion and dissolution of deuterium into
     said metal and activity of said deuterium in said metal.

     3.   A process as in claim 2 wherein the metal is selected

25   from the group consisting of transition metals and their
     alloys.

     4.   A process as in claim ?, wherein said transition metal
     is torched palladium having a porous structure.

     5.   A process as in claim 2, wherein said alkali deuteride

30   is lithium deuteride.

     6.   An electrolytic cell comprising:

          a substantially non-aqueous molten salt;

          an alkali deuteride dissolved in said salt to form an
     electrolytic solution;

35   a metal immersed in said electrolytic solution; ˙nd

          means for applying an electrical potential and current
     density to said metal and said electrolytic solution.

1   the group consisting of transition metals and their alloys.
     8. A process for electrochemically-assisted nuclear
     reaction, comprising:
         dissolving an alkali deuteride into a substantially non-
5   aqueous liquid salt to form an electrolytic solution;
         immersing a metal in said electrolytic solution; and
         applying a sufficiently high electrical potential and
     current density to said metal and said electrolytic solution
     to diffuse sufficient amounts of deuterium into said metal
10   at sufficient activity to initiate the nuclear reaction.
     9. A process for electrochemically-assisted nuclear
     reaction, comprising:
         dissolving an alkali earth metal deuteride into a
     substantially non-aqueous liquid salt to form an
15   electrolytic solution;
         immersing a metal in said electrolytic solution; and
         applying a sufficiently high electrical potential and
     current density to said metal and said electrolytic solution
     to diffuse sufficient amounts of deuterium into said metal
20   at sufficient activity to initiate the nuclear reaction.
     10. A process for electrochemically-assisted nuclear
     reaction, comprising:
         dissolving a Group IIIA metal deuteride into a
     substantially non-aqueous liquid salt to form an
25   electrolytic solution;
         immersing a metal in said electrolytic solution; and
         applying a sufficiently high electrical potential and
     current density to said metal and said electrolytic solution
     to diffuse sufficient amounts of deuterium into said metal
30   at sufficient activity to initiate the nuclear reaction.
     11. A process for electrochemically-assisted nuclear
     reaction, comprising:
         dissolving an alkali tritide into a substantially non-
     aqueous liquid salt to form an electrolytic solution;
35   immersing a metal in said electrolytic solution; and
         applying a sufficiently high electrical potential and
     current density to said metal and said electrolytic solution
     to diffuse sufficient amounts of triti

1 sufficient activity to initiate the nuclear reaction.
   12. A process for electrochemically-assisted nuclear
   reaction, comprising:
        dissolving an alkali earth metal tritide into a
5 substantially non-aqueous liquid salt to form an
   electrolytic solution;
        immersing a metal in said electrolytic solution; and
        applying a sufficiently high electrical potential and
   current density to said metal and said electrolytic solution
10 to diffuse sufficient amounts of tritium into said metal at
   sufficient activity to initiate the nuclear reaction.
   13. A process for electrochemically-assisted nuclear
   reaction, comprising:
        dissolving a Group IIIA metal tritide into a
15 substantially non-aqueous liquid salt to form an
   electrolytic solution;
        immersing a metal in said electrolytic solution; and
        applying a sufficiently high electrical potential and
   current density to said metal and said electrolytic solution
20 to diffuse sufficient amounts of tritium into said metal at
   sufficient activity to initiate the nuclear reaction.
   14. A process as in any one of claims 8 to 13, wherein said
   substantially non-aqueous liquid salt comprises a molten
   salt.
25 15. A process as in claim 14, wherein said molten salt is
   selected from the group consisting of organometallic salts,
   alkali halides, alkali hydroxides and mixtures of them.
   16. A process as in any one of claims 8 to 13 wherein said
   metal is selected from the group consisting of transition
30 metals and their alloys.
   17. A process as in claim 16 wherein said transition metal
   is selected from the group consisting of titanium,
   palladium, vanadium, tantalum, niobium, zirconium, nickel,
   cobalt, iron and their alloys.
35 18. A process as in claim 8, wherein:
        said applying step dissociates said alkali deuteride
   into an alkali and deuterium gas;
        wherein only a diffused portion of said deuterium

1   initiates said nuclear reaction leaving a remaining portion
     of said deuterium gas which evolves out of said solution;
     and
          wherein said alkali accumulates in said solution;
5   further comprising:
          reacting said alkali with said remaining deuterium gas
     and with additional deuterium gas to form an alkali
     deuteride; and
          dissolving said alkali deuteride into said electrolytic
10   solution to recycle said alkali and said deuterium.
     19.   A process as in claim 18, wherein said alkali is
     lithium.
     20.   A process as in claim 19, wherein said salt is a
     lithium chloride-potassium chloride eutectic salt heated
15   above 350 degrees Celsius.
     21.   A process as in claim 20, wherein said metal is
     palladium.
     22.   A process as in claim 21, wherein said palladium is
     torched palladium having a porous structure.
20   23.   A process as in claim 22, wherein said electrical
     potential is at least 1.8 volts and said current density is
     at least 200 milliamps per square centimeter.
     24.   An electrolytic cell having a recycling system,
     comprising:
25   a crucible;
          an inert gas contained in said crucible providing an
     inert gas atmosphere;
          a substantially non-aqueous molten salt melted in said
     crucible in said inert gas atmosphere;
30   an alkali deuteride dissolved in said salt to form an
     electrolytic solution;
          a first electrode comprising a metal selected from the
     group consisting of tungsten, molybdenum, nickel, iron and
     their alloys, immersed in said electrolytic solution;
35   a second electrode comprising a metal selected from the
     group consisting of palladium, titanium, tantalum, vanadium,
     nickel, niobium, iron, cobalt, zirconium, and their alloys,
     immersed in said electrolytic solution; and

15

1   means for applying an electrical potential and current
density to said electrodes and said electrolytic solution,
whereby:

         said alkali deuteride is electrolyzed into an alkali and
5   deuterium, whereby:

         a diffused portion of said deuterium is diffused into
said second electrode to generate excess heat;

         a remaining portion of said deuterium is evolved as
deuterium gas; and

10   said alkali is deposited onto said first electrode;

         a source of additional deuterium gas;

         means for combining said remaining deuterium gas and
said additional deuterium gas with said alkali to form an
alkali deuteride; and

15   means for dissolving said alkali deuteride into said
electrolytic solution.

         25.   A cell as in claim 24 wherein said alkali is lithium.

         26.   A cell as in claim 24, wherein said first electrode
comprises molybdenum.

20   27.   A cell as in claim 24, wherein said second electrode
comprises palladium.

         28.   A cell as in claim 27, wherein said palladium is
torched palladium having a porous structure.

         29.   An electrolytic cell, comprising:

25   a molybdenum crucible;

         a lithium chloride-potassium chloride eutectic salt in
said crucible, wherein said salt has been heated above 350
degrees Celsius to form a molten salt;

         sufficient amounts of lithium deuteride dissolved into
30   said molten salt to form an electrolytic solution;

         a positive electrode comprising torched and remelted
palladium immersed in said electrolytic solution;

         a negative electrode comprising molybdenum immersed in
said electrolytic solution and spaced apart from said first
35   electrode;

         a source of electrical current density and voltage
capable of applying a current density of at least 200
milliamps per square centimeter at a voltage of at least 1.8

1   volts between said first and second electrodes;
        whereby said electrical current density and voltage
    dissociate said lithium deuteride into lithium and
    deuterium;
5   whereby a diffused portion of said deuterium diffuses
    into said palladium in said positive electrode and a
    remaining portion of said deuterium evolves as deuterium gas
    at said positive electrode;
        whereby said lithium is deposited as liquid lithium
10 metal at said negative electrode and floats to said surface;
        means for combining said liquid lithium metal and said
    remaining portion of said deuterium gas to create recycled
    lithium deuteride; and
        means for introducing said recycled lithium deuteride
15 into said electrolytic solution.
        30. An electrolytic cell, comprising:
            a crucible;
            a heat source for heating said crucible;
            a lithium chloride-potassium chloride eutectic salt in
20 said crucible, wherein said salt has been heated by said
    heat source above 350 degrees Celsius to form a molten salt;
            sufficient amounts of lithium deuteride dissolved into
    said molten salt to form an electrolytic solution;
            a negative electrode comprising porous molybdenum
25 immersed in said electrolytic solution;
            a positive electrode comprising torched and remelted
    palladium immersed in said electrolytic solution underneath
    said negative electrode;
            a source of electrical current density and voltage
30 capable of applying a current density of at least 200
    milliamps per square centimeter at a voltage of at least 1.8
    volts between said positive and negative electrodes;
            whereby said electrical current density and voltage
    dissociate said lithium deuteride into lithium and
35 deuterium;
            whereby a diffused portion of said deuterium diffuses
    into said palladium in said positive electrode and a
    remaining portion of said deuterium evolves into unused

17

deuterium gas bubbles at said positive electrode and said
unused deuterium gas bubbles float upwards into said
negative electrode;

　　　whereby said lithium is deposited as liquid lithium
metal in said negative electrode;

　　　whereby said unused deuterium gas reacts with said
liquid lithium metal to form recycled lithium deuteride and
whereby said recycled lithium deuteride dissolves into said
electrolytic solution.

10   31.　An electrolytic cell, according to claim 29 or 30,
wherein said salt is heated in an inert gas environment.

32. An electrolytic cell, according to claim 31, wherein
said environment is at least at atmospheric pressure.

33.　An electrolytic cell, according to claim 31, wherein

15   said environment is below atmospheric pressure.

34.　An electrolytic cell, according to claim 29 or 30,
wherein said salt is heated in a deuterium environment.

35.　An electrolytic cell, according to claim 34 wherein
said environment is at least at atmospheric pressure.

20   36.　An electrolytic cell, according to claim 34, wherein
said environment is below atmospheric pressure.

37.　An electrolytic cell, according to claim 29 or 30,
wherein said salt is heated in an evacuated environment.

38.　An electrolytic cell, according to claim 29 or 30,

25   further comprising:

　　　means for introducing additional deuterium gas below the
surface of said electrolytic solution whereby additional
deuterium gas bubbles to the surface of said electrolytic
solution.

30   39.　An electrolytic cell, according to claim 38, wherein
said solution is an unsaturated electrolytic solution.

40.　An electrolytic cell, according to claim 38, wherein
said solution is a saturated electrolytic solution.
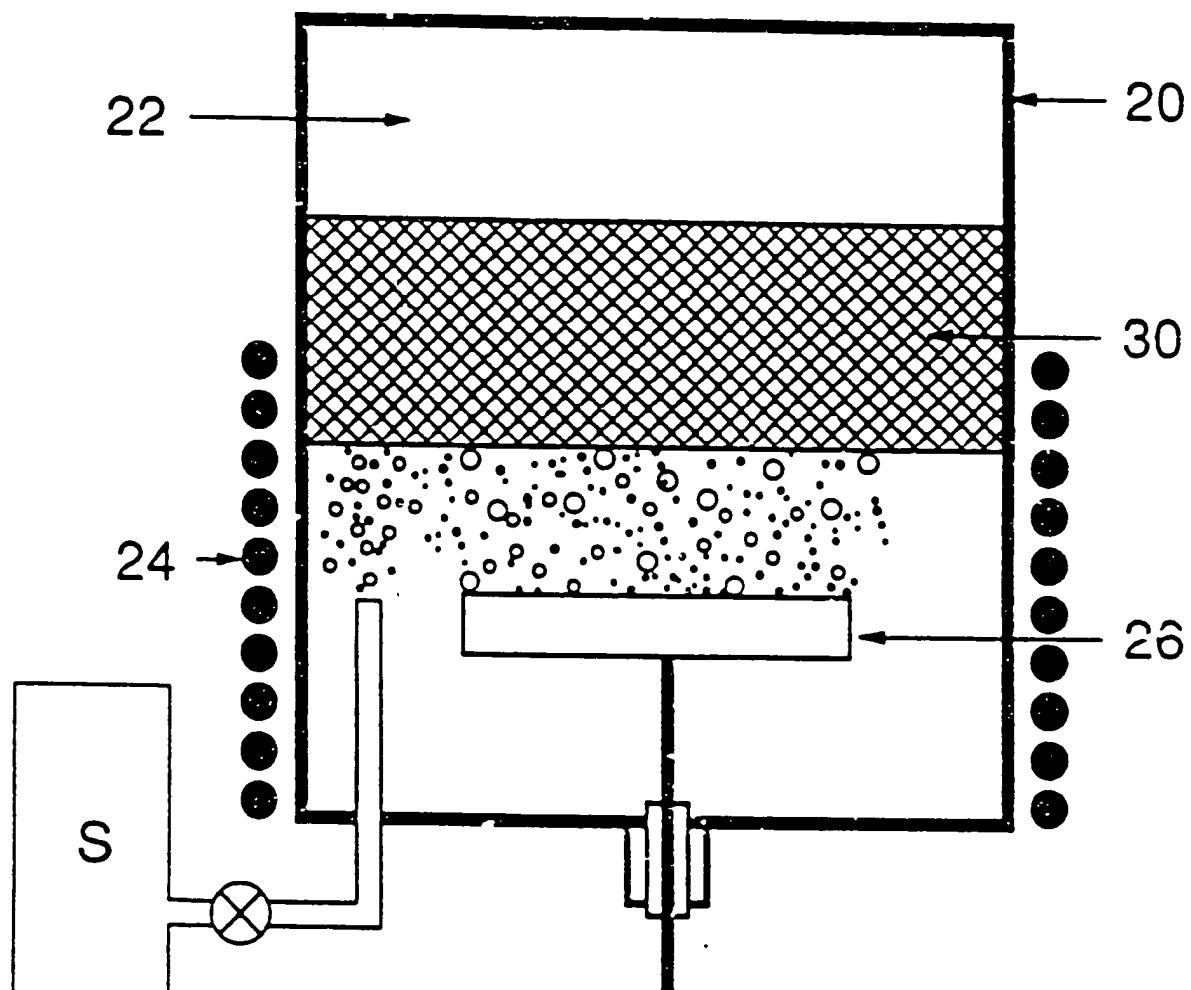
FIGURE 4

I. CLASSIFICATION OF SUBJECT MATTER   (if several classification symbols apply, indicate all)⁶

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 G21B1/00

II. FIELDS SEARCHED

	Minimum Documentation Searched⁷
Classification System	Classification Symbols
Int.Cl. 5	G21B

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched⁸

III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹

Category°	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No.¹³
P,X A	WO,A,9 013 127 (CERAMATEC) 1 November 1990 see page 3, line 35 - page 6, line 9 see page 7, line 5 - line 14 see claim 8 ---	1-8 14-17 9
P,Y	WO,A,9 013 125 (BRIGHAM YOUNG UNIVERSITY) 1 November 1990 see page 7, line 6 - page 8, line 10 see claims 1-4,6 ---	1
P,Y	EP,A,0 392 324 (SEMICONDUCTOR ENERGY LAB.) 17 October 1990 see column 1, line 39 - line 55 see column 2, line 18 - line 26 --- -/--	1

° Special categories of cited documents : ¹⁰

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
19 NOVEMBER 1991	2 5 NOV 1991
International Searching Authority	Signature of Authorized Officer
EUROPEAN PATENT OFFICE	CAPOSTAGNO E.

2
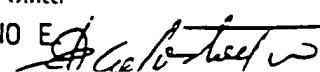
III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
P,A	FUSION TECHNOLOGY. vol. 18, no. 3, November 1990, LAGRANGE PARK, ILLINOIS US pages 505 - 511; ILIC ET AL.: 'Investigations of the deuterium-deuterium fusion reaction in cast, annealed, and cold-rolled palladium' see abstract	4-5

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.

US 9006419
SA 51620

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A-9013127	01-11-90	None	
WO-A-9013125	01-11-90	None	
EP-A-0392324	17-10-90	JP-A- 2271289	06-11-90